Leaky regions

Tim Harris

Microsoft Research

Introduction

Hypothesis: even when storage is managed by a garbage collector, it's usually possible to say when a given object can be destroyed

- GC means that:
  - The programmer doesn't have to figure this out
  - It can vary between apps, e.g. for library code
- Plus there are the oft-claimed GC advantages e.g.
  - Allocation is usually fast
  - Object retention leads to bloat rather than crashes

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Introduction (ii)

- People are still worried about the cost and timing of GC
- From a Singularity discussion:

```
loop {
  BeginTask(resource estimates, deadline);
  ... do time-sensitive work ...
  EndTask(out actual resources used, out slack time);
  waitForNextFrame();
}
```

- Can we identify blocks of code like this BeginTask...EndTask block where objects allocated in the block are expected to be destroyed by the time the block ends?
- Can we exploit this to (i) reduce the cost of GC and (ii) control when work occurs?

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Leaky regions

- Basic idea: annotate method calls saying "most objects allocated in this call will be dead when it returns"
- Safe: runtime checks for violations

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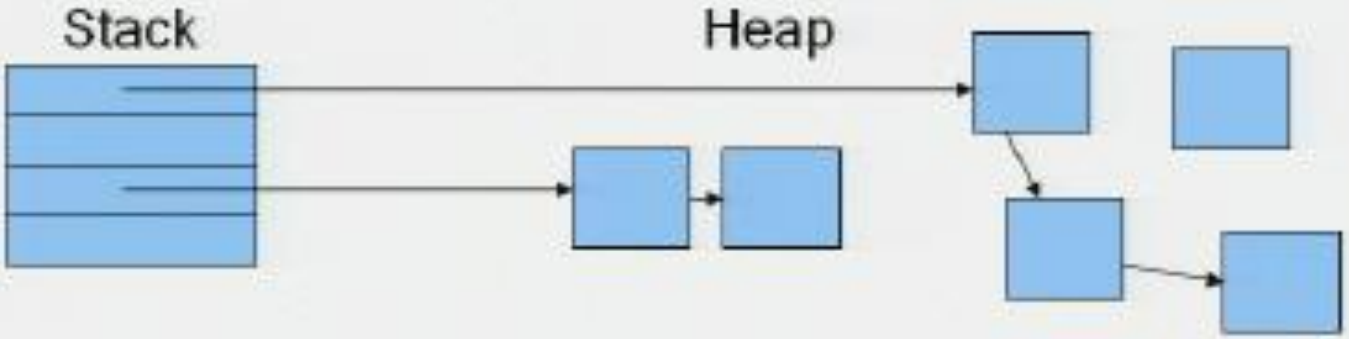

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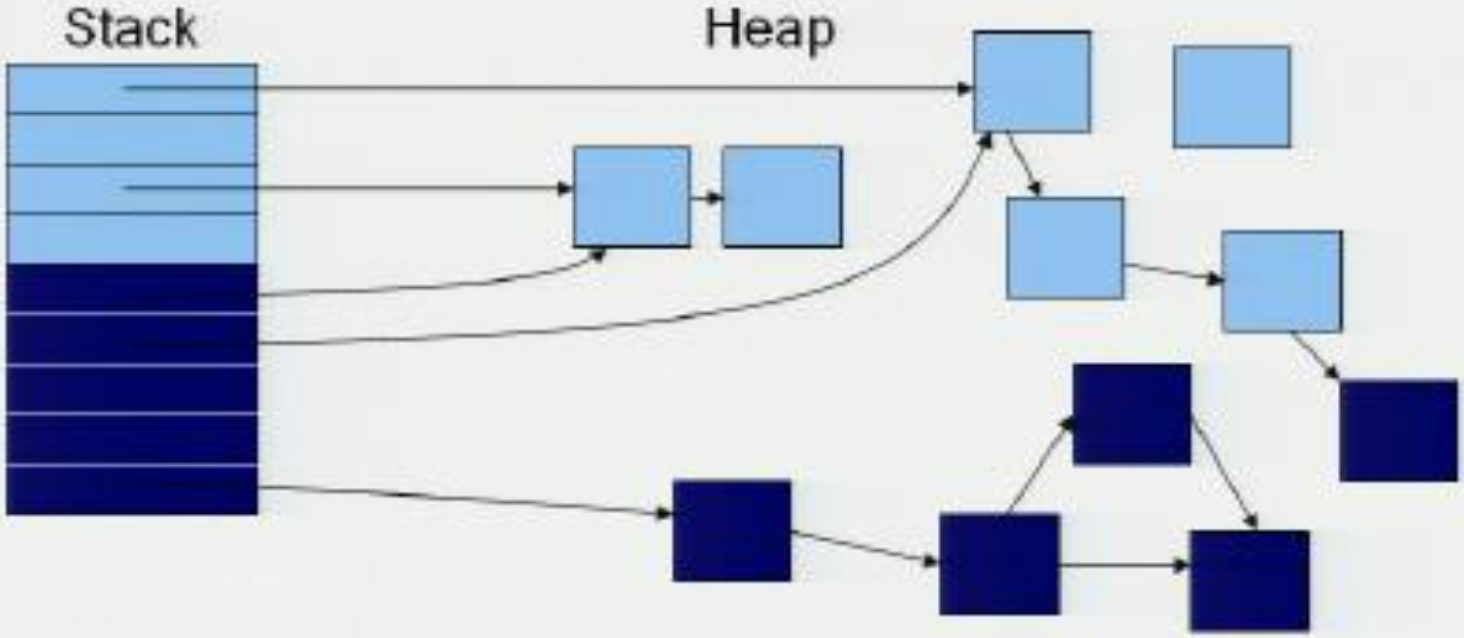

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Leaky regions

- Basic idea: annotate method calls saying "most objects allocated in this call will be dead when it returns"
- Safe: runtime checks for violations
- Three main costs in a naïve system:
  - Checking when an object leaks
  - GC-scope entry/exit code
  - Fragmentation between GC-scopes (e.g. one per page)
- Key assumption:
  - Objects rarely leak from GC-scopes

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Research context

- A lot of existing work on region-based collection (Tofte+Talpin '94)
- More restrictive form in RTSJ

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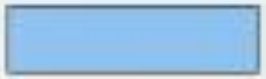
Heap

- Push a new region



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- Push a new region
- Allocate space in any of the regions

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Research context

- A lot of existing work on region-based collection (Tofte+Talpin '94)
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- Push a new region
- Allocate space in any of the regions
- Pop & deallocate a region

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Research context (ii)

- Escape analysis for on-stack allocation (OOPSLA '99)
  - As with region systems, must be proven safe
  - Per-method granularity
  - Risks of stack overflow
- Adaptive region-based allocation (Qian+Hendren, ISMM '02)
  - Mark allocation sites escaping / non-escaping
  - Won't tolerate objects that escape and are recaptured
  - Slightly better than per-method granularity
  - Looks at memory-related stats, not performance

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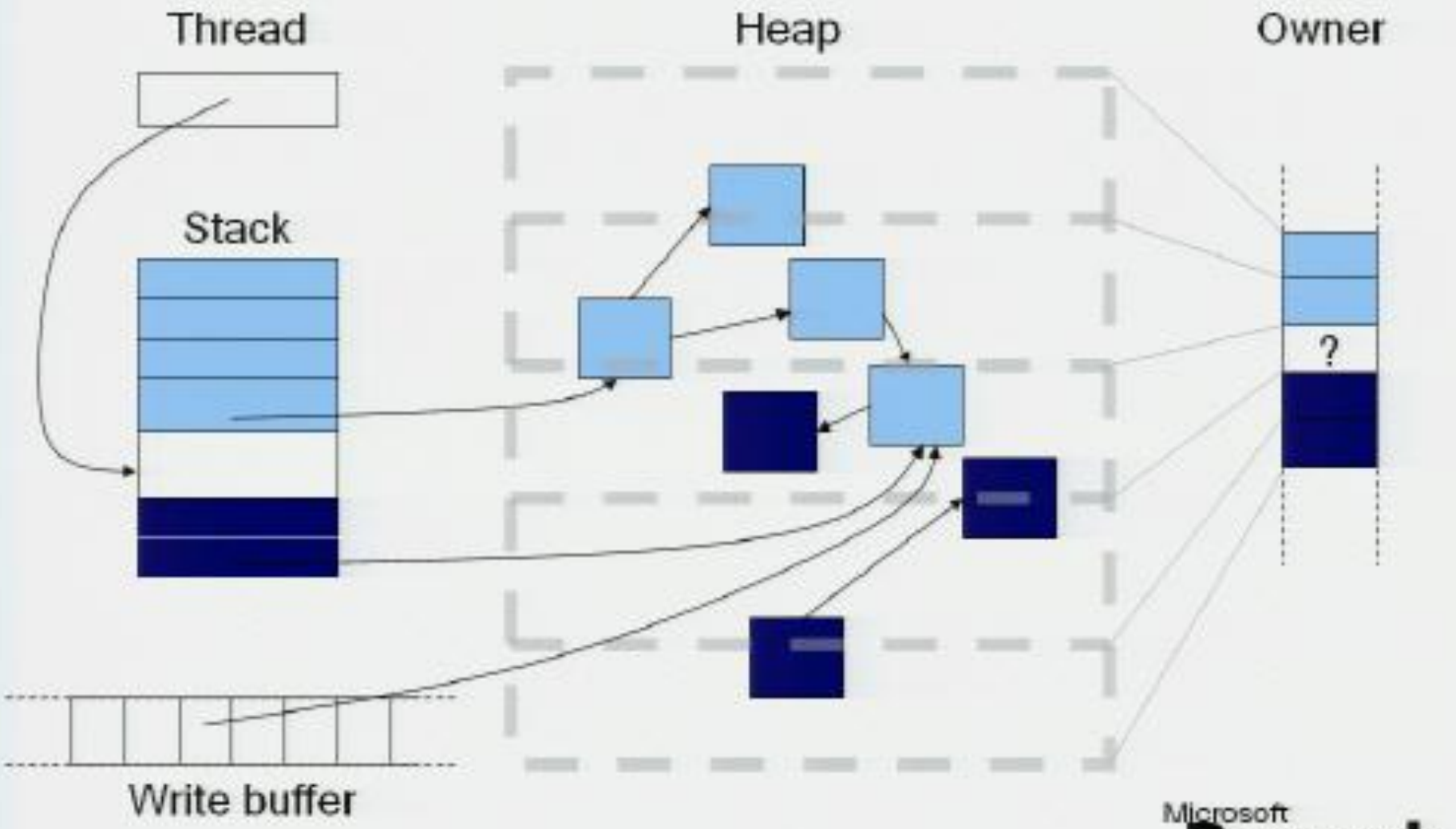
Implementation



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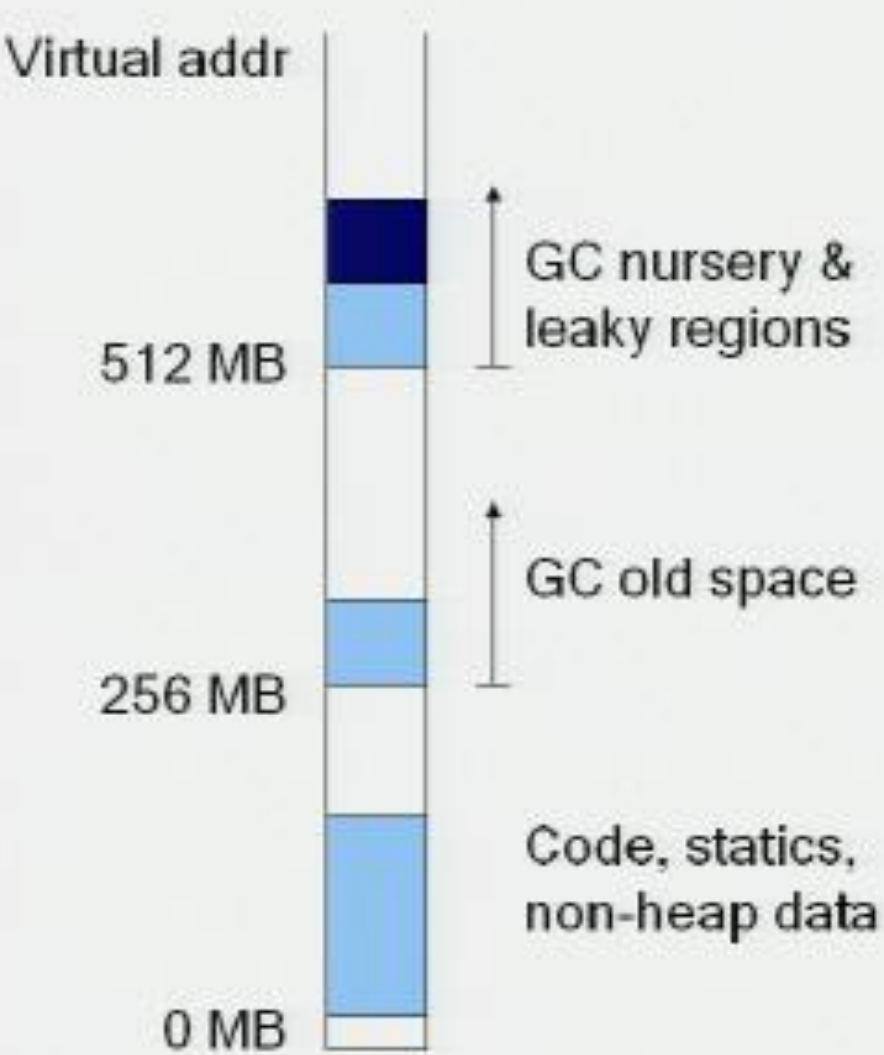
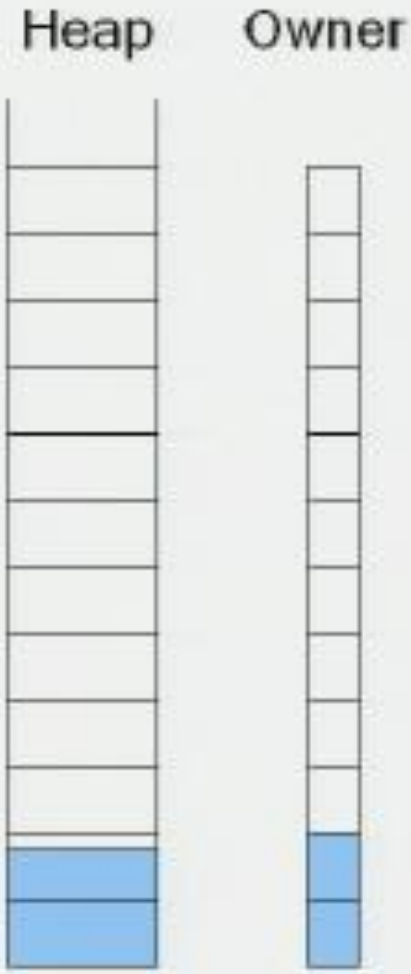
Implementation (ii)





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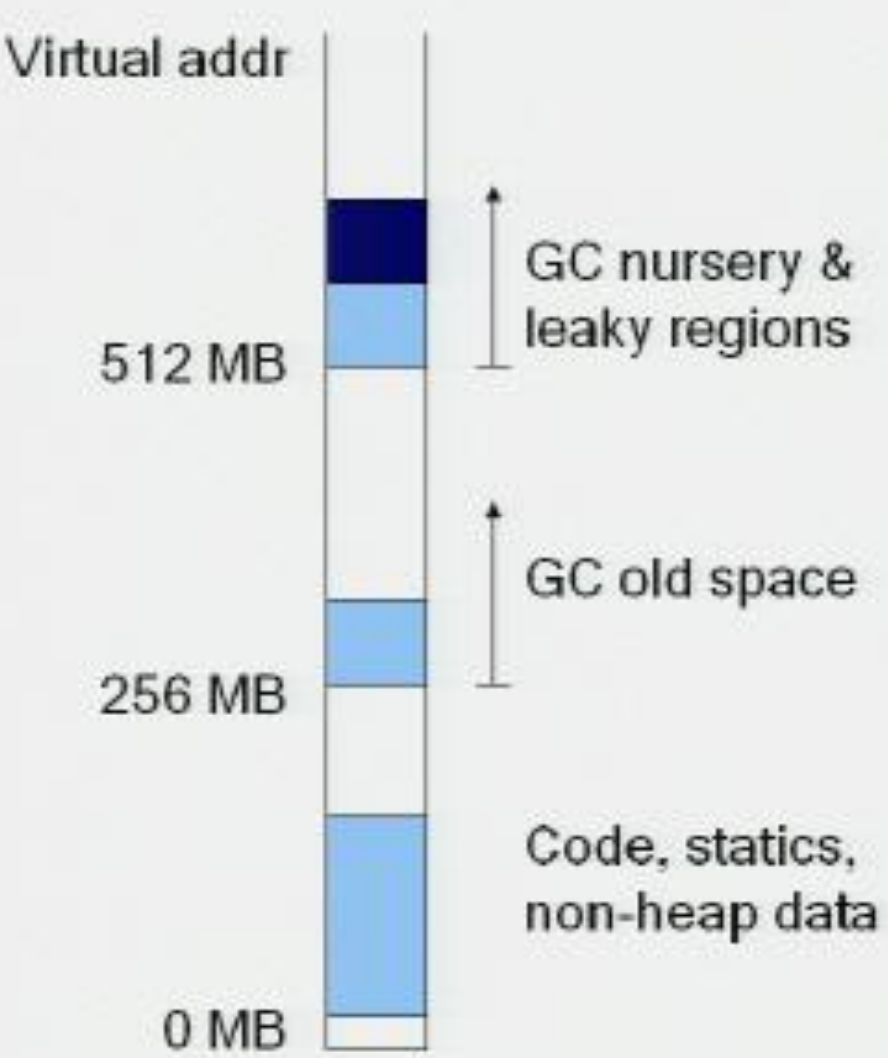

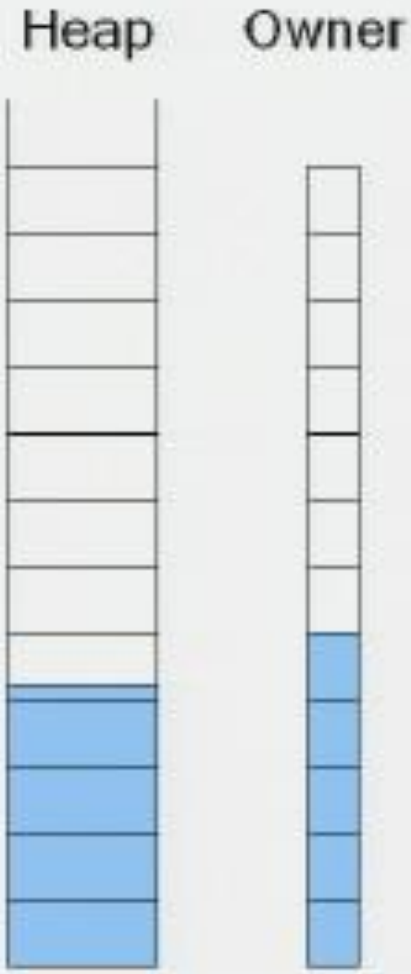

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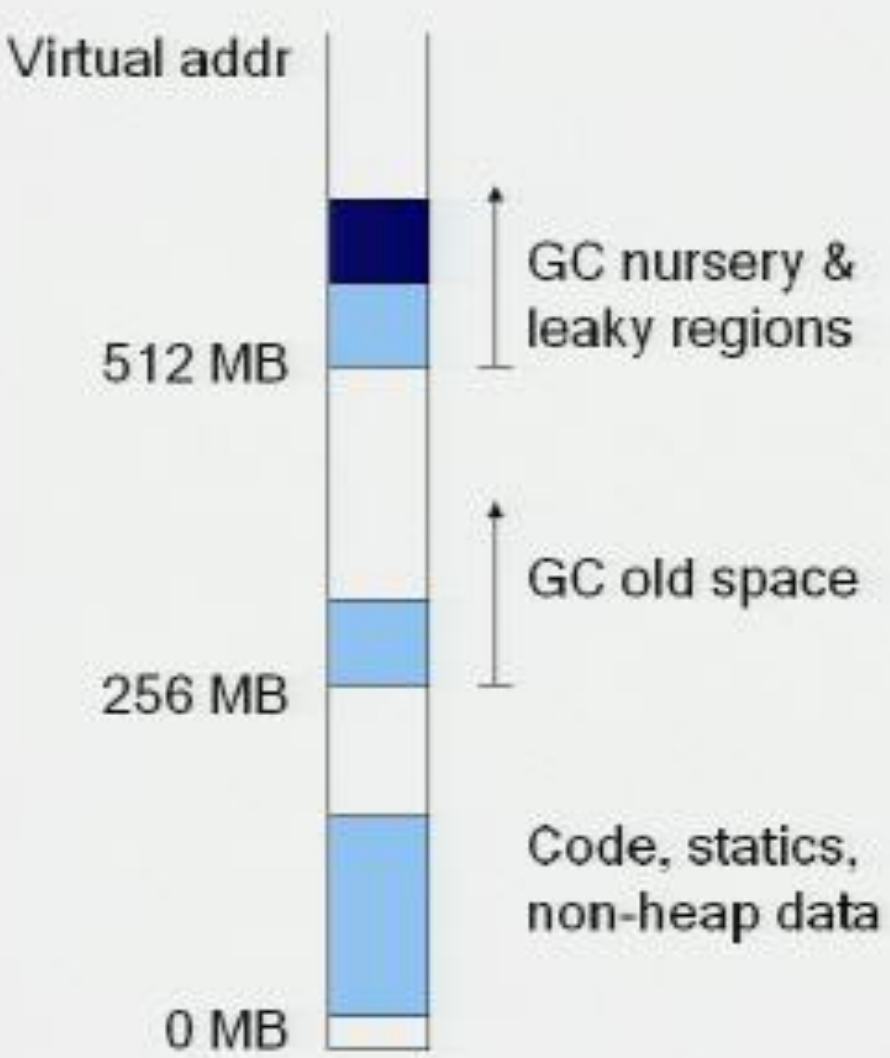

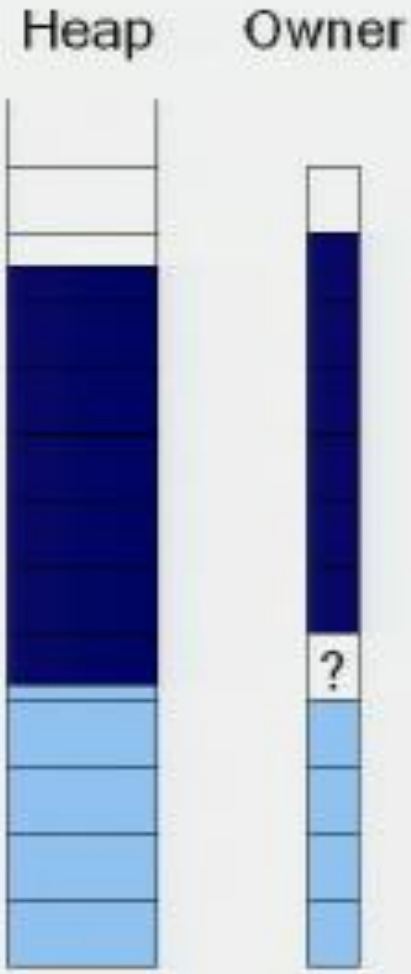

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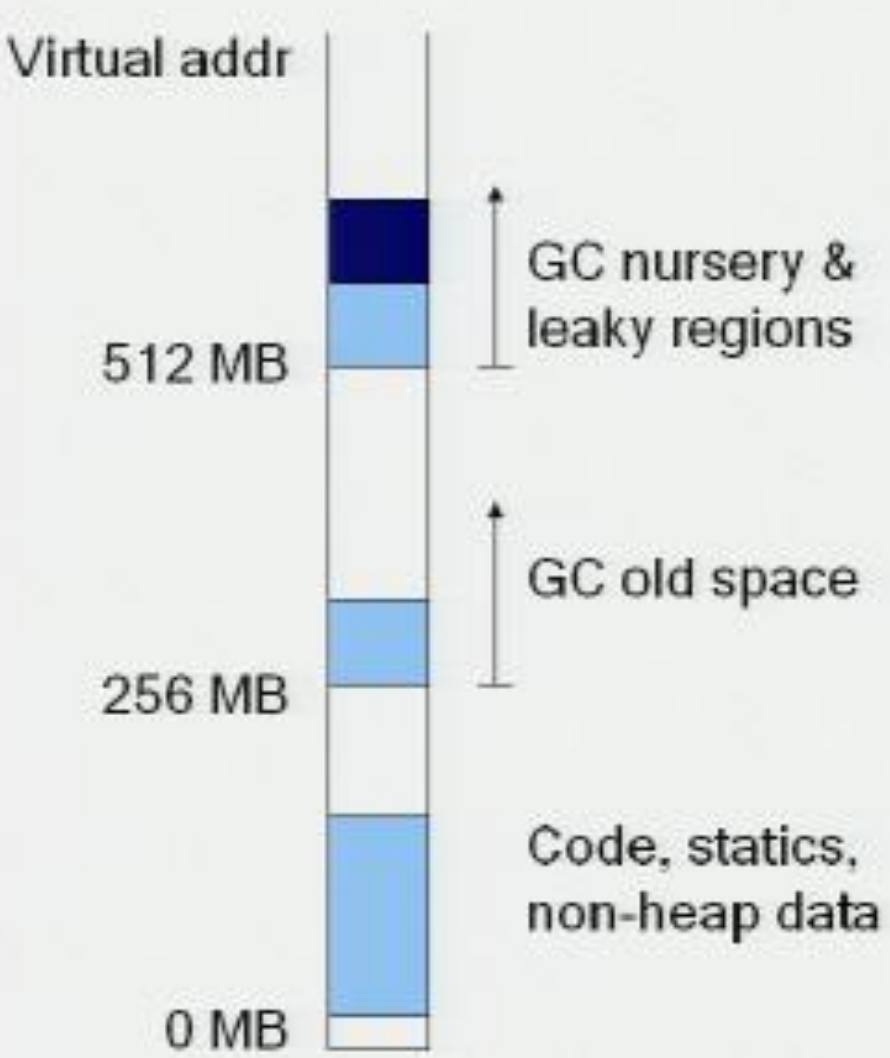

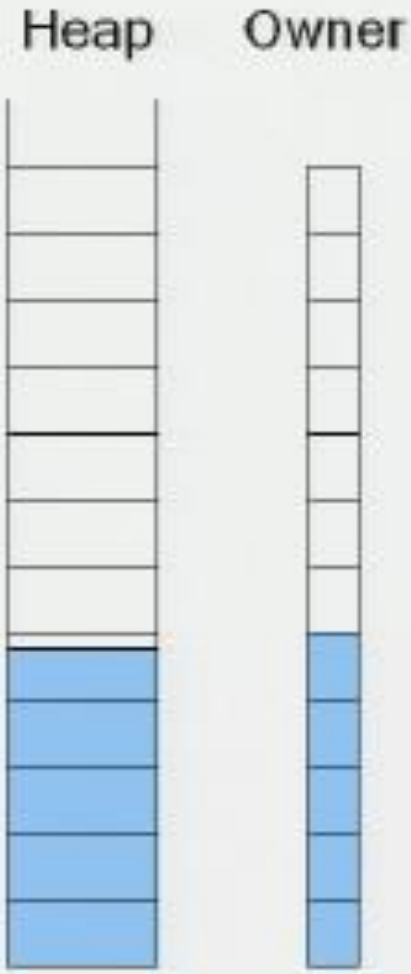

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Annotations (xlisp)

	Calls	Allocation footprint	
impact.li_130.xlisp..ctor -> impact.li_130.xlisp.xlload	20	2061013320	99%
impact.li_130.xlisp.xlload -> impact.li_130.xlisp.xleval	281	2058795532	99%
impact.li_130.xlisp.xleval -> impact.li_130.xlisp.evform	41048456	2058795532	99%
impact.li_130.xlisp.evform -> impact.li_130.xlisp.func	28756528	2058782718	99%
impact.li_130.xlisp.xleverg -> impact.li_130.xlisp.xleval	32000688	2058710020	99%
impact.li_130.xlisp.evfun -> impact.li_130.xlisp.xleverg	14449211	2058704812	99%
impact.li_130.xlisp.evform -> impact.li_130.xlisp.evfun	2445802	2058703180	99%
impact.li_130.xlisp.xlevlist -> impact.li_130.xlisp.xleval	34219881	2055798568	99%
impact.li_130.w_xcond.func -> impact.li_130.xlisp.xleverg	2703585	1994337804	96%
impact.li_130.xlisp.evform -> impact.li_130.xlisp.xlevlist	17948325	1521302440	73%
impact.li_130.xlisp.evform -> impact.li_130.xlisp.xlevlist	2445802	1510122408	73%
impact.li_130.xlisp.tagblock -> impact.li_130.xlisp.xleverg	4603864	1339567852	64%
impact.li_130.w_xdo.func -> impact.li_130.xlisp.doloop	112743	1335780852	64%
impact.li_130.xlisp.doloop -> impact.li_130.xlisp.tagblock	2562724	1334083528	64%
impact.li_130.xlisp.xlgetvalue -> impact.li_130.xlisp.xlxgetvalue	78751788	1280034392	61%
impact.li_130.xlisp.xleval -> impact.li_130.xlisp.xlgetvalue	78731784	1259714328	61%
impact.li_130.w_xlet.func -> impact.li_130.xlisp.let	90581	1205580718	58%
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Annotations (xlisp)

- impact.li_130.w_xdo.func -> impact.li_130.xlisp.doloop:
  - 112743 invocations
  - 1215MB allocated
  - 1210MB reclaimed
  - 0.4MB leaked
- impact.li_130.xlisp.evform -> impact.li_130.xlisp.evfun
  - 2445902 invocations
  - 1209MB allocated
  - 807MB reclaimed
  - 0.3MB leaked
- Many objects leaked temporarily through static fields
- Leaked objects are lisp heap segments

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Annotations (crafty)

- Crafty.Net.OO.MoveGenerator.Search -> Crafty.Net.OO.MoveGenerator.ABSearch
  - 84767 invocations
  - 217MB allocated
  - 217MB reclaimed
  - 0.5MB leaked
- 87% allocation footprint
- Leaks come from checking for board-state repetitions

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Annotations (go, ijpeg)

- impact.go.go.Main -> impact.go.go.getmove
  - 296 invocations
  - 709MB allocation footprint
  - 704MB reclaimed
  - No leaks
  - Fairly large allocation volumes per invocation => little reclamation with small young generation
- Two calls to go_execute_compression_and_decompression
  - 128 invocations
  - 28MB allocation footprint
  - 28MB reclaimed
  - 0.07MB leaks (arrays in spec_define_subimage_int)

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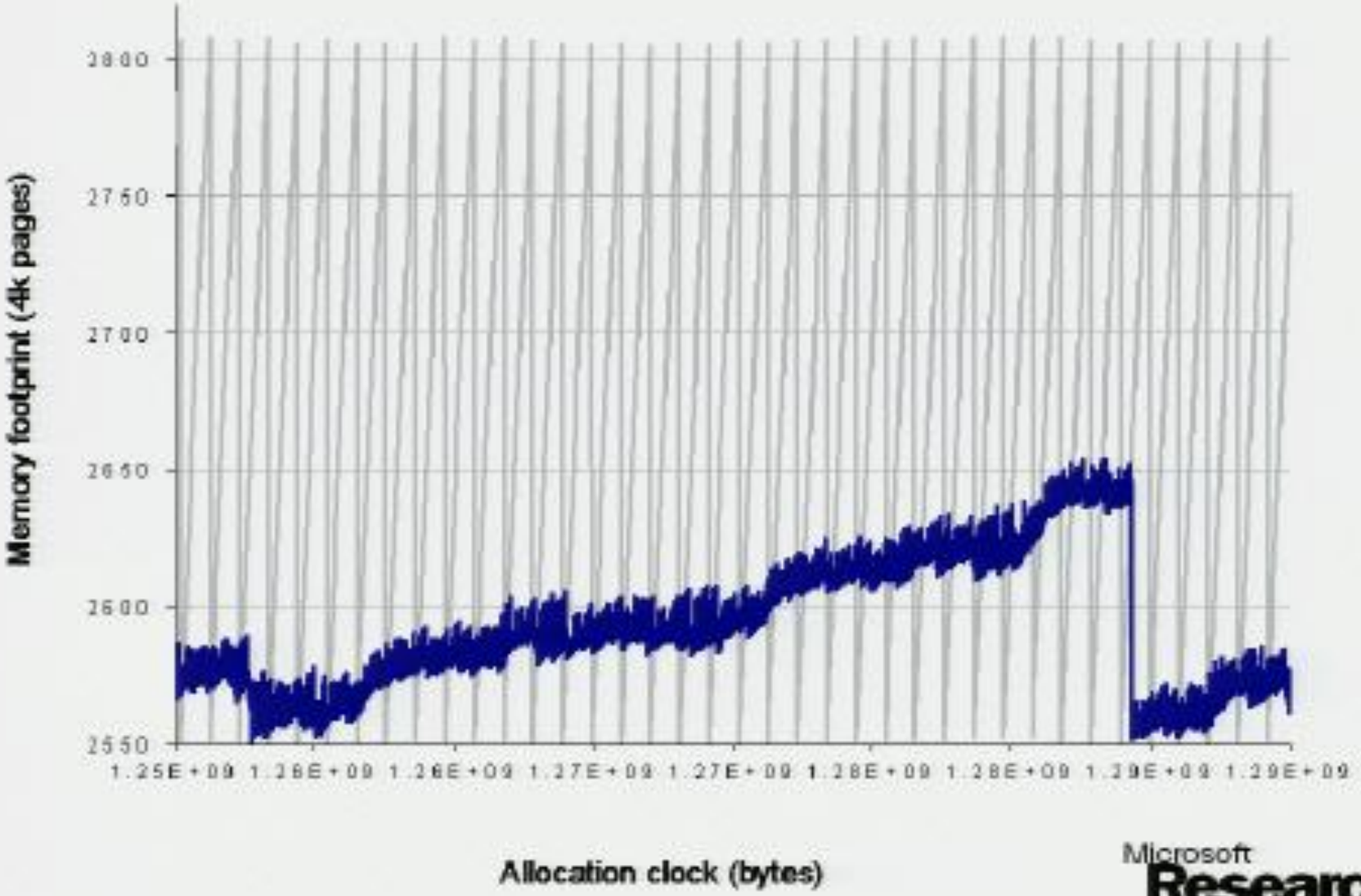
Results (xlisp)



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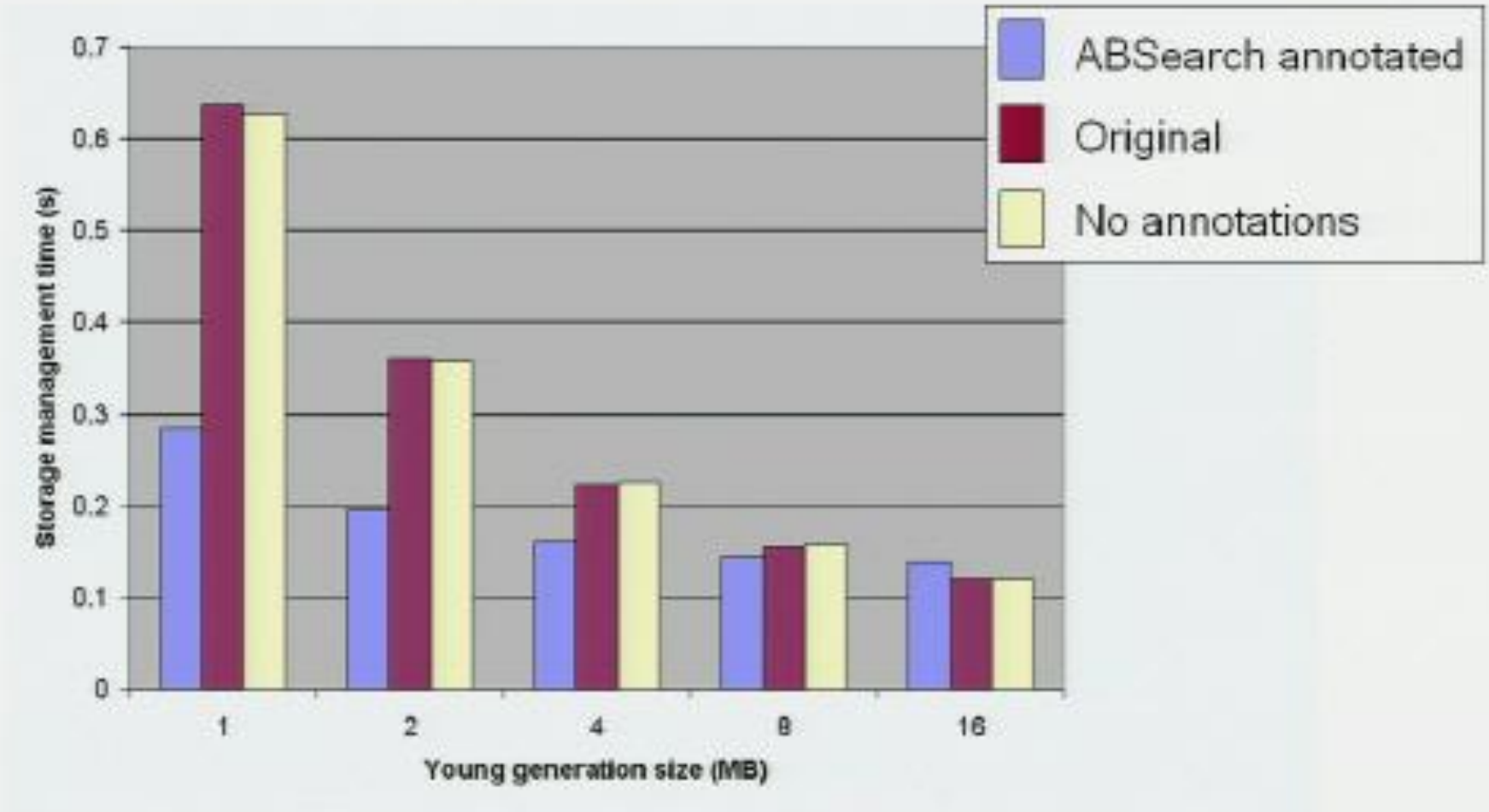
Results (crafty)



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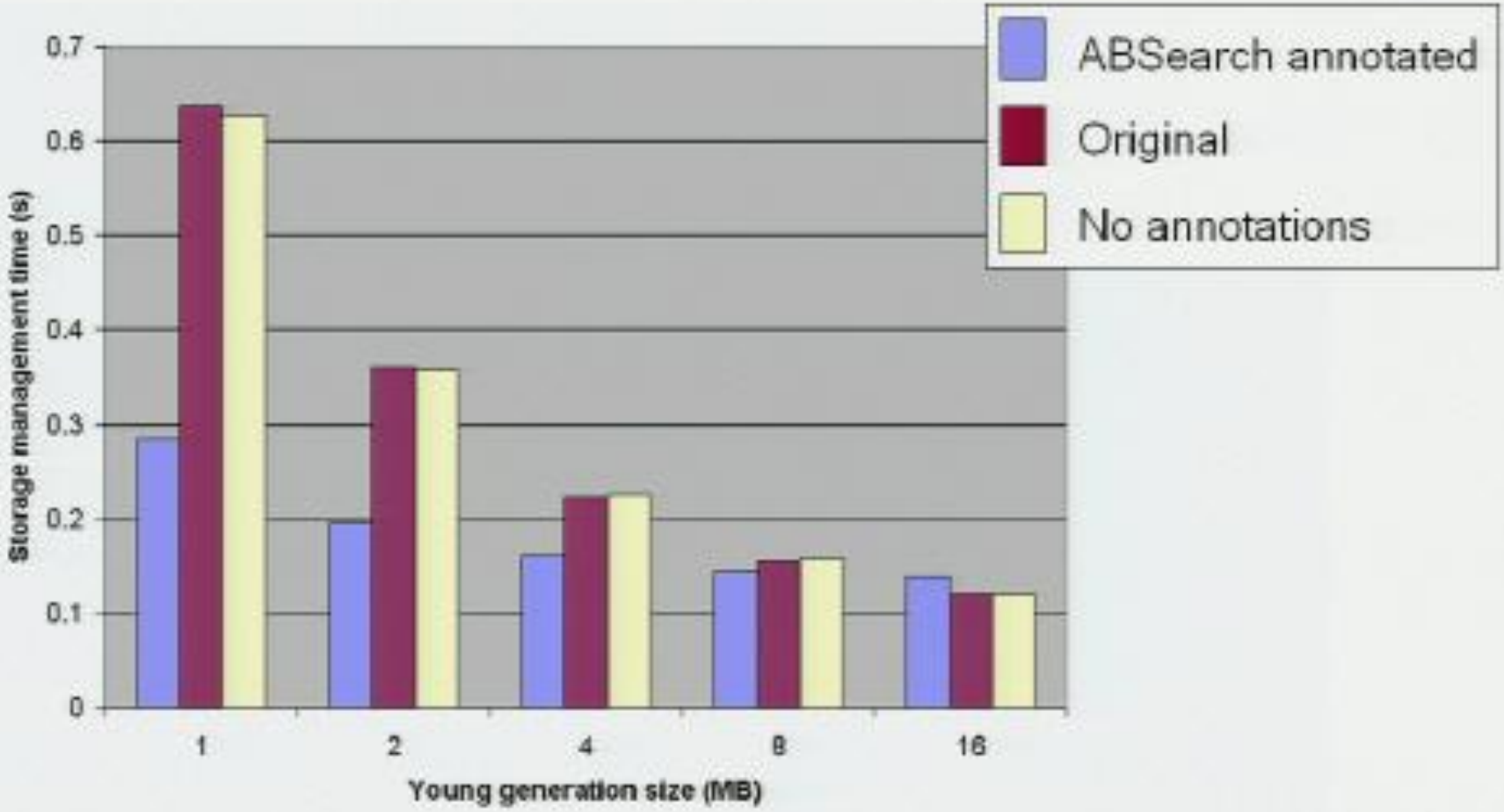

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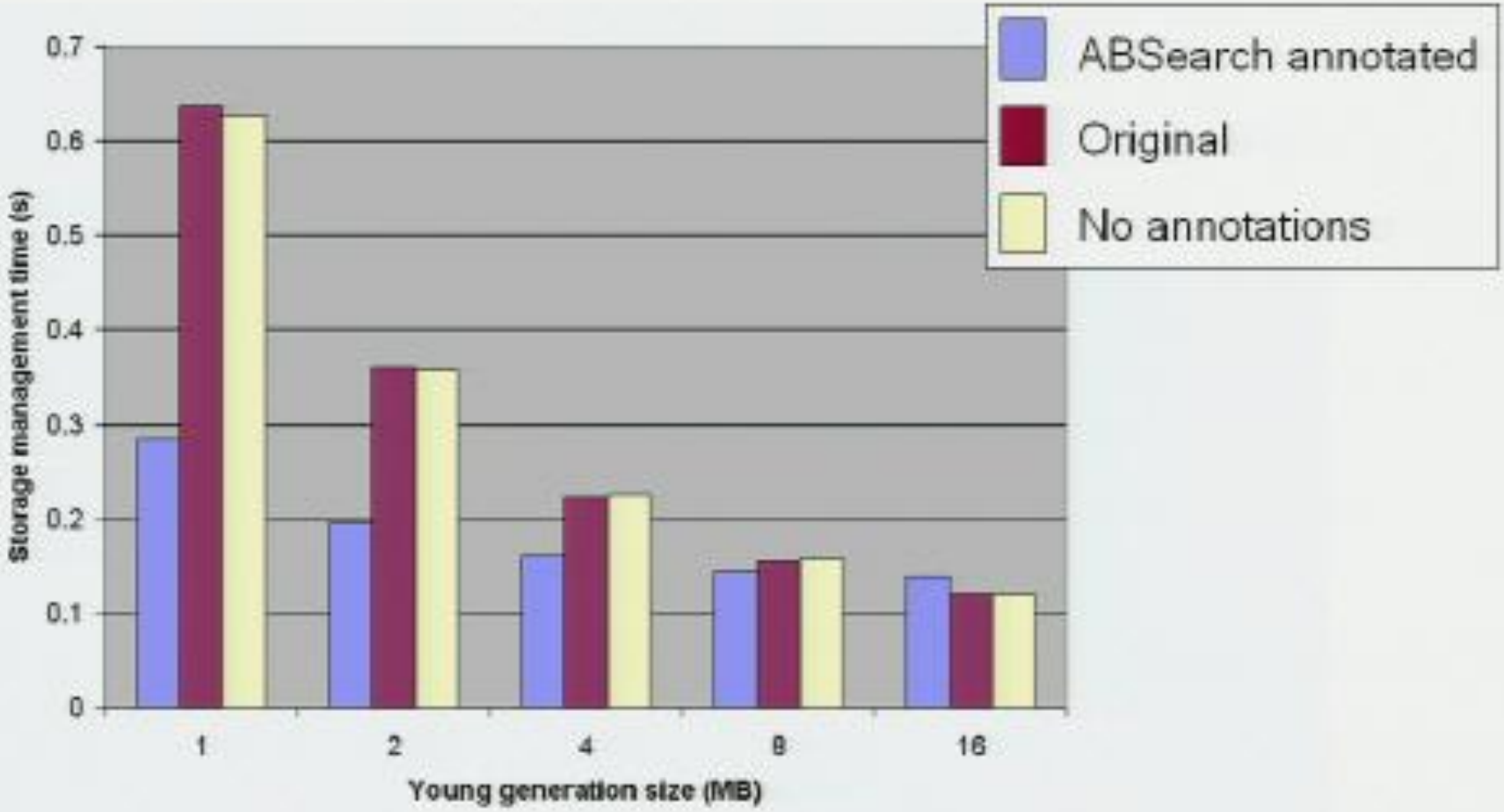

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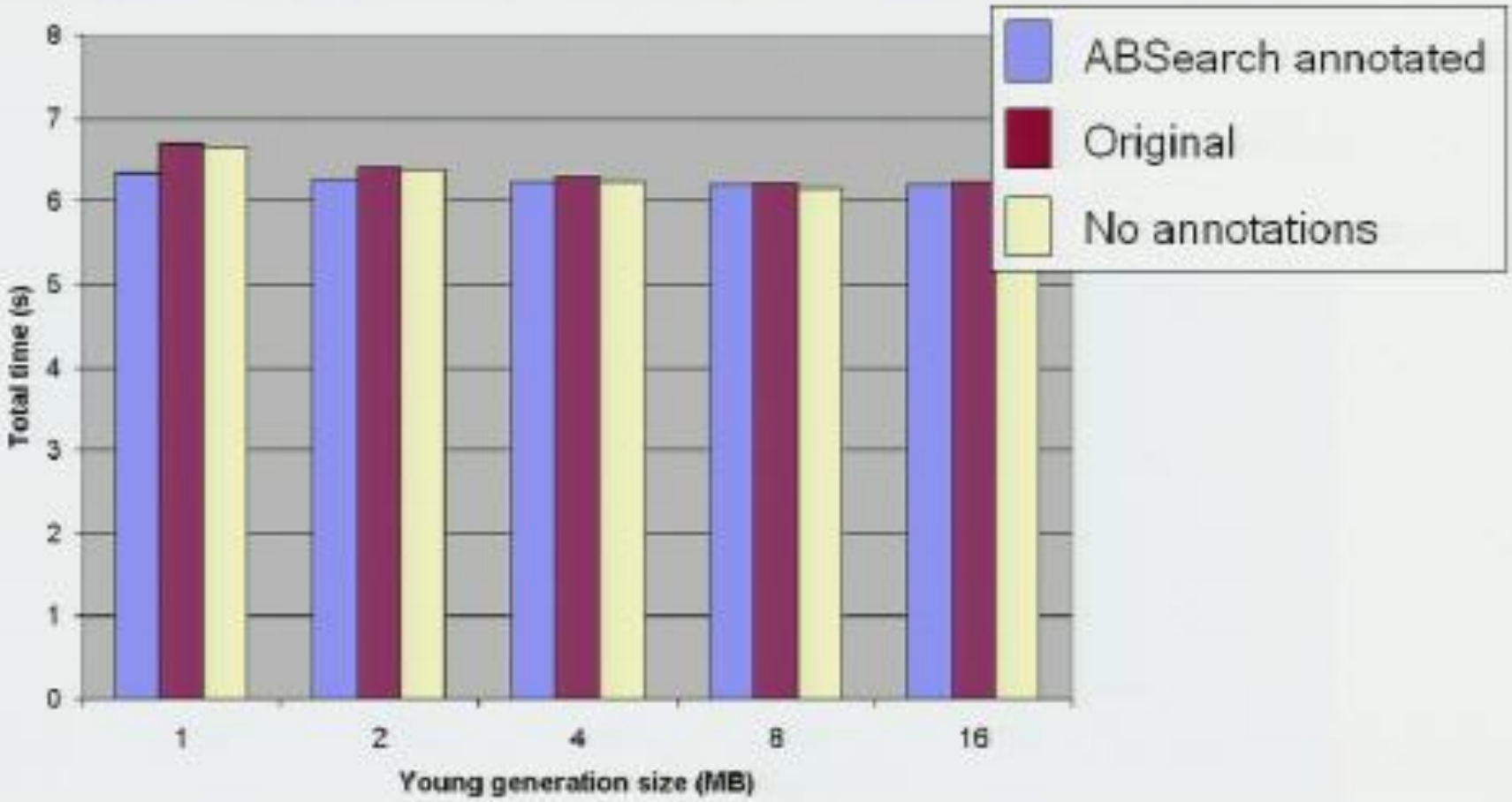

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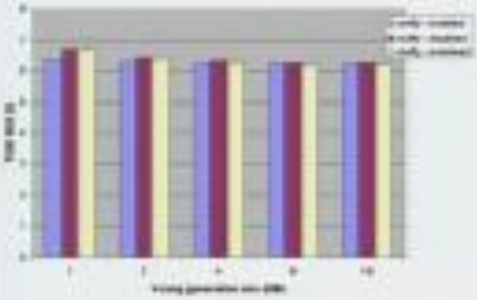
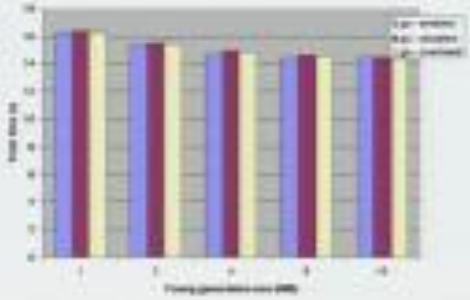
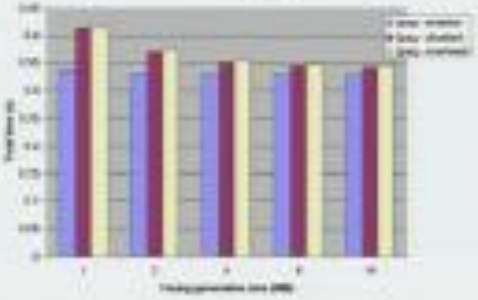


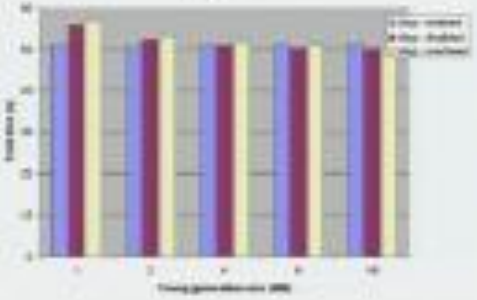
go

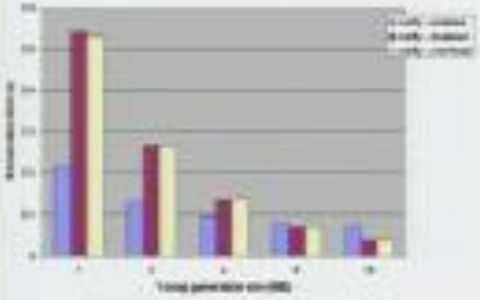


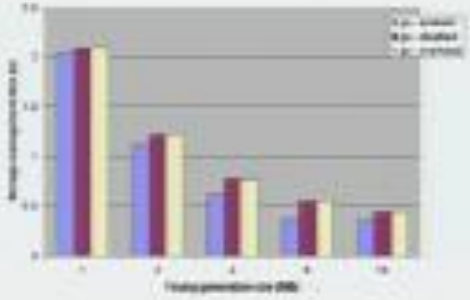
ijpeg

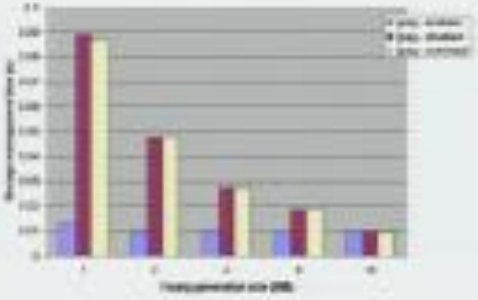


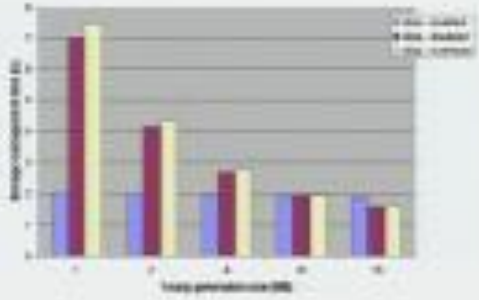
xlisp

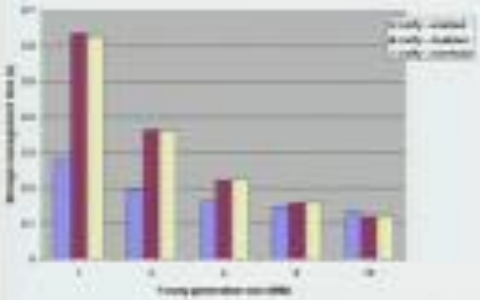


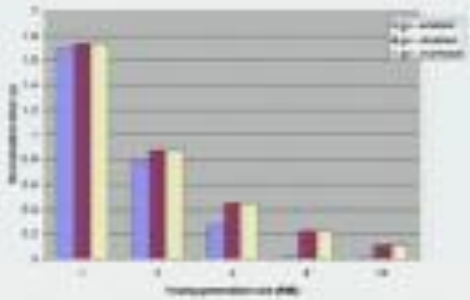


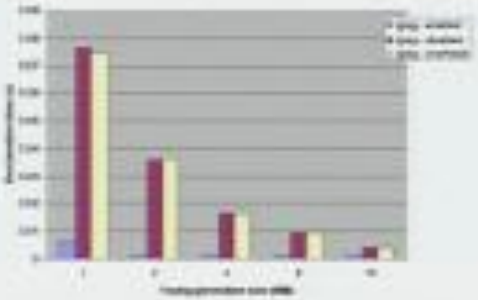


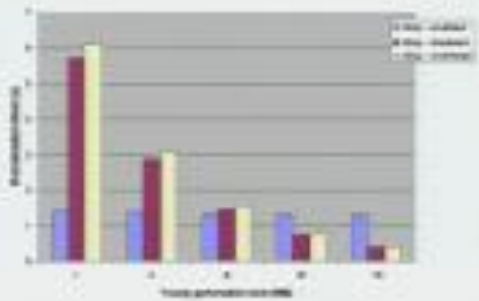












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Conclusions

- Practical run-time costs unlike previous work
- Evaluation shows the value of
  - Recapturing escapees
  - Considering more than individual method calls
- Picking the boundary is important
  - Few calls, little leakage, large portion of total allocation
  - Scope for feedback-directed choice
- Evaluation with other collectors
  - Other kinds of write barrier
- This is all single threaded...

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